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MINE COUNTERMEASURES AT THE OPERATIONAL LEVEL OF WAR

by

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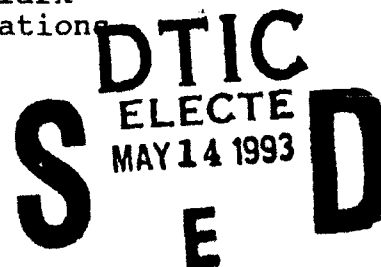
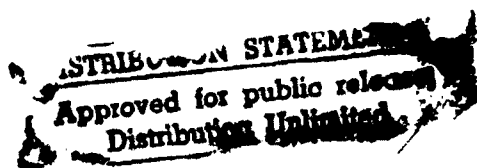
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The contents of this paper reflect my own personal views and are not necessarily endorsed by the Naval War College or the Department of the Navy.

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PREFACE

U.S. Navy mine countermeasures (MCM) is a complex combat support mission area that until recently was relatively unfamiliar to most naval operational commanders and their staffs. Appendix I is included to further enhance the reader's knowledge of types and characteristics of naval mines. The sources include historical publications and recent periodicals (1989-1993) on mine warfare and mine countermeasures in the U.S. Navy. Some portions of the paper draw heavily upon the author's eight years of experience in Explosive Ordnance Disposal MCM operations and exercises. Research material was acquired from the U.S. Naval War College and author's personal library.

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MINE COUNTERMEASURE OPERATIONS AT THE OPERATIONAL LEVEL OF WAR

CHAPTER 1

INTRODUCTION

The purpose of this paper is to provide the reader with a basic understanding of mine countermeasure operations and mine warfare at the operational level of war. It is not intended to be a technical document nor focus on the tactical aspects of mine countermeasures. The primary objective is to develop a basic conception of the difficulties of deploying mine countermeasure assets in the theater of operation. Furthermore, this paper does not focus on any specific MCM capability or problem (i.e. shallow water versus very shallow water tactics) but provides a general overview of employing today's MCM assets.

To understand the concept of incorporating MCM into the operational art of warfare, it is most beneficial to draw on the annals of history - for the same mistakes made in the past are often repeated. Therefore, the author has devoted a chapter to mine warfare history followed by operational and employment considerations and concluding with a hypothetical present-day scenario.

Chapter II

Overview of the History of Mine Warfare

Beginning in 1776 until our most recent conflict, Desert Storm, the U.S. Navy has been involved in mine warfare. The naval mine is considered by most weapons' experts an inexpensive, cost-effective, offensive and defensive weapon. When properly employed, the mine is one of the most difficult weapons to counter available in today's weapons inventory. In order to employ combat forces by sea, an operational commander (CINC, ATF, JTF, etc.) must always be conscious of the hidden mine threat when planning an operation.

There are many diverse factors to be considered when dealing with a possible mined area. The fact that an area could possibly be mined is sufficient reason in itself to alter a well-thought-out plan due to the possible loss of valuable assets and most important, human life.

Minefields achieve (their) goal principally through the enemy's perception of the threat the mines pose... The psychological threat from a minefield is the result of, first, the inability to know with certainty the true threat and, second, of the risk of dire consequences if the threat proves to be underrated.¹

Invention of Bushnell's Sea Mine. The first known sea mine was invented in 1776 by an American, David Bushnell. The mine was a simple wooden keg filled with gunpowder and hung by a float. In 1777, during the American Revolutionary War,

Bushnell set a number of the kegs adrift in the Delaware River for the purpose of damaging a fleet of British warships anchored in the harbor. To Bushnell's chagrin, the attempt failed; however, his effort set the stage for future employment of the naval mine.

American Civil War. The naval mine was first used effectively during the American Civil War. The Confederates needed a weapon that was inexpensive and could be produced in large numbers to protect the vast southern coastline and break the Union blockade. The naval mine did not prevent the Union from executing an effective blockade; however, it did delay the progress of the blockade and consequently prolonged the war. The Confederate mines sank twenty-seven U.S. Navy vessels which included several iron clads. Of particular note, Admiral Faragut's success during the Battle of Mobile Bay was not attributable so much to tenacity and seamanship as to ineffective mines (due to long emersion and subsequent wave action) laid by the Confederates.

World War I. During World War I, the Allies laid over 70,000 mines in the North Sea, stretching from Scotland to Norway, to set up a giant defensive barrage to close German U-boat exits. This giant effort began in June 1918 and ended before completion due to the Armistice. This proved to be an effective strategic weapon, sinking at least six submarines

and damaging many more. Additionally, this was psychologically frustrating for the German submarine crews - wasting valuable time and fuel before entering their designated target zones. All total, mines were credited with sinking eighty-nine submarines and damaging or sinking over 1.4 million tons of allied shipping. Thus, the mine had played a very important role in naval warfare strategy.

The sea mine, being considered a "dirty weapon" by the international community, was all but forgotten after World War I. With the advent of World War II and the German's doctrine of unrestricted warfare on allied shipping, the Allies devoted a tremendous amount of money, time, and effort to mine development - utilizing airplanes, submarines and ships as mine-laying platforms.

The contact mine was still considered effective but could be "countermeasured" by improvements in mine countermeasure capabilities leading to the development of influence mines. As opposed to technologically outdated contact mines, the influence mine or "smart mine" employed electronic detectors that responded to magnetic, pressure, and acoustic ship signatures to "fire" or detonate the mine.

Influence mines were mainly used as "bottom mines" - mines that would explode underneath a ship, produce a violent explosive bubble, and, in many cases, break the ship's keel. These "smart mines" also contained mine counter-countermeasure (MCCM) devices to protect themselves against sweeping and

other forms of countermeasure. The first two MCCM devices were the delayed arming mechanism and ship counter. Until this day, these types of World War II influence mines still pose a formidable weapon for mine countermeasure forces to defeat. It was not until the last stages of World War II that influence mines were used, but they placed a tremendous burden on both the Allies' and Axis' mine countermeasure forces. They not only had to deal with destruction of these mines but with the new MCCM devices also.

Operation Starvation. Operation Starvation is one of the most famous employments of influence mines during World War II. This operation was carried out in the last five months of the war by the U.S. XXI Bomber Command against Japanese shipping in the Pacific. Of particular note, this operation was carried out utilizing only about six percent of bomber sorties available. Modified United States' bombers laid over twelve thousand mines (influence) in Japanese shipping lanes, harbor approaches, and channels, sinking over 1.25 million tons of Japanese shipping and totally disrupting all maritime traffic. Japan lacked the MCM capabilities and expertise to deal with these modern weapons. Japanese ships that were not sunk became easy prey for American submarines and aircraft attack - as ships were either forced to stay in port or diverted to already over-crowded ports. It was

apparent this mining operation was more effective than all bombing and incendiary raids conducted.

Korea. During the Korean Conflict, the North Koreans, utilizing sampans and junks, effectively laid over three thousand moored and bottom mines at Wonsan. This delayed the American amphibious landing by sixteen days giving the North Koreans time to retreat. As a consequence, the United States paid a heavy price with the loss of two hundred sailors and two mine sweepers.

In the words of Rear Admiral Holke Smith:

When you can't go where you want, when you want to, you haven't got command of the sea, and command of the sea is the rock bottom foundation for all of our war plans. We've been plenty submarine conscious and air conscious. Now we're going to start getting mine conscious - beginning last week.²

Unfortunately, the U.S. Navy expended very little effort in updating or modernizing its MCM forces following Korea.

Lou Gerkin summed it up in the following statement.

The real picture of mine warfare in the U.S. Navy is that it has a low priority and is the first to be cut when budget reductions must be made. The level of interest can be traced back to Alfred Thayer Mahan, the founder of doctrine of the modern U.S. Navy. He disliked mines, calling them an unnecessary burden on a navy intent on achieving command of the sea. Mahan believed that mines constituted a mode of warfare that those who commanded the seas did not want, and which if successful, would deprive them of it. The British admirals of the time believed the same, perhaps this influenced him.³

Receiving a low priority in research and development, MCM capabilities continued to deteriorate for the next three decades.

Vietnam. In 1972 the U.S. Navy, utilizing modified aircraft bombs, "Destructors", laid mines in Haiphong Harbor. This offensive employment of mine warfare effectively blockaded this vital Vietnamese port for over three hundred days. Following negotiations, the U.S. Navy cleared the harbor using air mine countermeasure (AMCM) forces. The Viet Cong also scored some success with their use of crude drifting mines which were easily assembled on the spot.

Desert Storm. Desert Storm brought to fruition the neglect of U.S. Navy MCM inefficiencies. Two U.S. Navy ships, *Princeton* and *Tripoli*, sustained damage due to mines. MCM forces were divided under five different Type Commanders resulting in command and control problems. Heavy lift vessels were utilized to transport mine sweepers to the Gulf for several reasons, among which were to conserve wear and tear on already taxed engineering components and difficulty in obtaining spare parts. This consequently created a delay in employment of much-needed surface mine countermeasures (SMCM) support. Fortunately, allied MCM assets were available to offset the U.S. Navy's limited MCM capabilities.

Chapter III

MCM Employment Considerations

Command and Control - Commander Mine Warfare Command (COMINEWARCOM) is operationally responsible for all MCM assets in the U.S. Navy. Home-ported in Ingleside Texas, COMINEWARCOM consists of two groups (GP1, GP2). Each Group consists of air (AMCM), surface (SMCM) and EOD dive teams. Current deployable resources for each group consists of one active duty squadron of MH-53E Sea Dragon helicopters, a mix of three to four mine countermeasure vessels (MCMV) (MCM-1 Avenger class ocean-going mine sweepers) and two EOD MCM detachments. COMINEWARCOM has been tasked to:

Maintain the capability to deploy commanders and supporting staffs capable of exercising operational control of mine warfare forces during peacetime operations and in response to two major regional contingencies in any theater or unified commander's area of responsibility.¹

Air Mine Countermeasures (AMCM) - The MH-53E helicopter with its speed and mobility is probably the logical deployable MCM asset of choice when time is a critical factor. The helicopter is capable of performing percussor mechanical and influence sweeps at speeds between forty and sixty knots. Disadvantages of the MH-53E in MCM operations include inability to sweep in deep water, use primarily under good weather conditions, and consumption of large amounts of fuel.

MCM operations are extremely taxing on the helicopter's crew and machinery. Furthermore, its mine hunting capabilities are limited and is considered inferior to a surface minesweeper's powerful sonar.

Surface Mine Countermeasures (SMCM) - The MCMVs

(Avenger Class) are the backbone of U.S. MCM assets. Equipped with sweep gear, variable depth sonar, and the AN/SLQ-48 Mine Neutralization System (remote operated vehicle),* these vessels are durable and can operate on-station for long hours. Excelling as mine hunters, MCMVs are also capable sweeping platforms. A major disadvantage of the MCMV is its lack of speed in getting to the area of operation (top speed twelve knots). Furthermore, sweeping requires reduced speed (six to eight knots maximum) and can be costly when time is a critical factor. Additionally, the method of choice for deploying MCMVs is the heavy lift vessel.

There are currently other MCM ships in the U.S. Navy inventory, the MHC (Mine Hunter Craft), Osprey-class, and a few older MSOs. The MHC is primarily a port-breakout ship for U.S. coastal waters. Additionally, the MHC is not yet deployable as it is presently undergoing research and development with only two in commission. All MSOs, with the

*The AN/SLQ-48 Mine Neutralization System (MNS) is an unmanned mine-hunting submersible. The vehicle is guided to the target by a small high-definition sonar. Additionally, the submersible has a camera for examination, cable cutters, and an explosive mine detonation charge.

exception of one, are currently assigned to the Naval Reserve Force.

Explosive Ordnance Disposal MCM Detachments - Explosive ordnance disposal (EOD) divers are specialty-trained underwater ordnance experts who receive extensive training in MCM operations. Their mission consists of assisting MCM forces in locating, neutralizing, and/or destroying mines in the theater of operation. Additionally, EOD personnel are invaluable intelligence assets, identifying mines and methods of actuation for an effective countermeasure operation. Each MCM detachment is equipped with a special "fly away" package for contingency and overseas operations. The package includes modern non-magnetic closed circuit diving systems (MK-16), specialized tools for mine recovery and render safe procedures, and gas (breathing) replenishment systems. EOD MCM detachments are normally assigned to each MCMV or other support craft.

There are several disadvantages of EOD MCM operations. MCM diving operations requires a slow, disciplined, and methodical process due to the inherent dangers involved with sensitive mines. Diving operations are generally only conducted in good weather and require dedicated small craft for actual diving platforms. EOD dive teams are usually restricted to a support role for AMCM, SMCM assets but can be used exclusively when search areas are limited and water depth does not exceed equipment/diving capabilities.

Chapter IV

Operational Considerations

Media - The operational commander and his staff must be keenly aware of defense media coverage/policy and address operational plans in such a manner that mission accomplishment or operational security is not jeopardized. Answers to media questions should be short, simple, and articulated in such a manner as to convey the message to the public in a positive manner, as the first media perception of the operation will affect public opinion. Therefore it is imperative that the operational commander understands the importance of keeping a low profile versus an opportunity to "tell his side of the story". Anytime a U.S. Navy ship strikes a mine, it certainly gets the public's attention.

Environment - Environmental and geographical features must be taken into account when commencing MCM operations. Sea state, tides and currents can impede mine sweeping and hunting operations. Poor visibility can restrict aerial reconnaissance and hamper the effectiveness of the EOD dive teams. Hydrography is important as MCM forces must be aware of bottom type, obstructions, and depth in planning successful operations.

Hostilities - It is inconceivable to operate an MCM force in a hostile environment. Mine hunting and sweeping requires a slow, disciplined, and predictable search pattern. Accuracy is imperative so that the area can be marked and chartered. MCM forces present the enemy with inviting targets with the MCMVs slow speed and the MH-53Es trailing sweep gear for several hundred feet. Furthermore, numerous sweeps may be required if it is suspected enemy mines are equipped with MCCM devices. Therefore, it is imperative that MCM forces operate in a benign environment.

Logistics - Logistics is one of the key centers of gravity in conducting military operations. MCM operations are no different and demand a cohesive effort of all available logistic assets. AMCM (helicopters) require a command platform for command and control as well as maintenance. Furthermore, MCMVs and AMCMs require fuel to operate - a consideration that must be taken into account due to possible fuel constraints in the area of operation. EOD MCM dive teams require dedicated spaces for dive personnel, equipment, explosives and portable air recompression chambers. Routinely, heavy-lift vessels for deployment of SMCM (MCMVs) will be utilized.

Intelligence - Intelligence gathering plays an enormous role when dealing with an impending mine threat. The most

effective mine countermeasure is to destroy the enemy's mine inventory and capability to lay mines before the event actually takes place.

According to Rear Admiral John D. Pearson,

In any future regional conflict, there are going to be two key things that we should do or consider. The first is having the capability for intelligence to tell us the types of mines that are going to be used and getting indications that mines are in fact being laid by a potential enemy. Part of our reorganization will result in a more focused approach to mine warfare intelligence, including systems to adequately monitor the enemy. In addition, once we arrive in an area and start mine-clearance operations, one of the first things we need to do is exploit a mine so we can verify what we suspect and find out if something new and different is being done. Secondly, we have also learned that we need to take every measure available to destroy the enemy's mine inventory and/or his capability to lay the mines as early as the international political scenario will allow.¹

Chapter V

Scenario

To focus on the difficulties the operational commander is confronted with when dealing with a mine threat, I have proposed a present-day hypothetical peacetime contingency operation to examine the actions a commander must undertake in order to accomplish his objectives. When confronted with a mine threat environment, the best option is to avoid the mine field entirely. For the purpose of this scenario, this option has been eliminated to give the reader an understanding of the concept of employing MCM in the amphibious objective area (AOA). Commander ATF 20.2 has been tasked to conduct a noncombat evacuation operation (NEO) for the purpose of evacuation of American citizens residing in Country Red.

Situation - An explosive political situation has erupted in Country Red. Following months of power struggles between the pro-American government and Marxist rebels, Country Red is now in a state of almost total anarchy. The opposition forces have been receiving state of the art weapons from a third party nation that is considered to be at odds with the government of the United States. There are approximately five hundred American citizens residing in Country Red, and they have been evacuated to the port city of Moldingo. Government forces are currently in control of the

city; however, heavy concentrations of insurgents are nearby. The Red forces have gained partial control of port facilities and are threatening to occupy the airport. Intelligence sources state that the situation is deteriorating, and it is estimated that Moldingo will fall within thirty days. Additionally, rebel forces have acquired several motor vessels capable of laying mines. To further complicate matters, the countries surrounding Country Red are considered either hostile or neutral.

To prevent the conflict from escalating, the National Command Authority has informed the amphibious task force (ATF) commander not to utilize any air space except that leading into Country Red itself. The U.S. forces have superior air power over Country Red forces; however, the mission is considered too dangerous to conduct an evacuation of American citizens utilizing air lift capabilities. The only MCM assets available to ATF 20.2 are two attached surface EOD detachments.** A carrier battle group is operating nearby to provide air support. It is estimated that there will be some resistance at the proposed landing site; however, nothing should prevent U.S. forces from securing a beachhead and evacuating U.S. citizens.

**Surface EOD detachments have a limited MCM capability due to their inherent mission which is basically surface oriented. Furthermore, they routinely are not equipped with nonmagnetic diving equipment - a requirement for diving on modern influence mines.

Following tasking, the operational commander commences operation; and as a screening destroyer from the ATF enters the vicinity of the Straits of Moldingo, it explodes and bursts into flames. Fires are put under control and the shipboard damage control teams are working at a frantic pace to save the ship. Several lives are lost and the media broadcasts over national television that the Port of Moldingo is mined and a U.S. Navy ship has been severely damaged. The ATF commander is now faced with very difficult and time-sensitive decisions.

Following an evaluation of enemy capabilities and reconnaissance of other possible amphibious landing sites, the operational commander elects to continue the mission as previously planned with Mine Warfare Command (MINEWARCOM) assistance. COMINEWARCOM assistance is requested via satellite communications. It is the only option as U.S. allies firmly oppose involvement and continue to remain neutral.

COMINEWARCOM assistance is confirmed and the following reply is received. MCM Group Two, consisting of an on-scene commander/staff, six MH-53E helicopters, three MCMVs, and an EOD MCM detachment has been assigned to the ATF for MCM operations. The MCM staff and EOD MCM detachment is scheduled to arrive within forty-eight hours. The MH-53E helicopters are being deployed on a LPH and expect to arrive within ten

days. The MCMVs are being placed on a heavy lift ship and should be in the AOA within seventeen days.

Upon arrival, the MCM Commander presents the following recommendations to the ATF commander:

- A. In conjunction with assigned EOD detachments and available helicopter assets for visual searches, commence reconnaissance missions for the purpose of locating a mine or mines for exploitation. Once identification is made of the mine type (bottom or moored) and method of actuation (contact or influence), a viable phased MCM operation plan can be developed, implementing AMCM forces upon arrival.
- B. Once AMCM forces arrive sweeping or hunting operations can proceed, weather permitting. However, the ATF Commander is reminded that helicopters have a limited mine hunting capability; and it may be necessary to wait on the arrival of the MCMVs.
- C. Once the MCMVs arrive, forces can be integrated and used in tandem.

Conclusions - Where does the operational commander go from here? Only the commander can balance his options and make recommendations to his immediate superior whether to abort the mission or modify his own course of action. Conducting an amphibious landing is a painstaking operation, consisting of a myriad of considerations: close air support,

landing zones, well deck operations, hydrography, sea state, special operations, landing craft, anti-air warfare (AAW), anti-surface warfare (ASUW), to name but a few. Adding a mine threat certainly complicates an already complex operation. To enhance success of any maritime contingency or operation, MCM requirements must be included in the adaptive planning process.

It is unrealistic, given today's U.S. limited MCM assets, to assign MCM forces to every maritime low intensity conflict (LIC); however, these forces must be considered if the adversary has mines/mine laying capabilities. Additionally having an MCM officer on the operational staff of the ATF could have assisted the operational commander immensely in the above scenario. MCM operations are slow and painstaking, normally consisting of mine-hunting and sweeping operations, with the former preferred over the latter. The operational commander must understand that clearing a minefield could possibly take months, depending on the density, MCM assets available, and type of enemy mines encountered.

In the previous scenario, it is apparent that the operational commander is going to be hard-pressed to meet his thirty day deadline which of course is only an intelligence estimate. The best solution to any mined area is integrated mine warfare that is using AMCM, SMCM and EOD MCM in tandem. Due to logistics problems, this may take weeks. The bottom

line - the operational commander must rely on the advice of the assigned mine warfare commander.

Chapter VI

Conclusion

Due to recent events in the Gulf and a recognition not only by the U.S. Navy but also by Congress of current MCM deficiencies, mine warfare is justly receiving a lot of attention. The decision to collocate MCM assets in one location, Ingleside, Texas, assuredly will increase readiness and training opportunities by allowing all assets to train in tandem. Navy leaders and the Department of Defense must keep the issue of a strong and viable MCM capability alive or, as history has often dictated, interest will decline. In the final analysis, it is apparent that today we have a limited capability to operate in a mine threat environment. The assets available are modern and effective but limited. The operational commander must understand this; and when MCM assets are required, he will be qualified to interpret the limited range of options available.

Appendix I

Mine Types - For simplicity and ease of recognition, modern sea mines are normally categorized by position assumed in the water, method of delivery (laying) and method of actuation.

When mines are classified by the position they assume in the water, they fall into three categories - bottom, moored, and drifting. The drifting mine has been all but eliminated from the world's inventory relevant to the Hague Convention of 1907. However, drifting mines have been infrequently employed by third world countries in the twentieth century.

Bottom mines are used primarily in shallow water (40 to 200 feet). Bottom mines are negatively buoyant, sink to the bottom, and after a period of time seem to disappear or become covered with the ocean bottom surface. This phenomenon, called "digging in", occurs as a result of shifting sand due to currents and wave action. This makes the mine extremely difficult to detect and poses an additional hazard during mine clearance operations.

Moored mines may be laid in shallow or deep water and are used against both submarines and ships. The positively buoyant case, which houses the explosive charge, is connected to a cable attached to a sea anchor on the bottom. This mine can be set at a predetermined depth for effectiveness. The moored mine is easier to detect and countermeasure than the

bottom mine; however, it is just as effective and deadly as the bottom mine to unsuspecting ships and submarines.

Aircraft-laid mines must be specially configured for air delivery. When mines are delivered by air, they are dropped in the same manner as a bomb. Offensive in employment, the aircraft-laid mine is used to replenish mine fields over an extended period of time without danger from previously laid mines. Aircraft-laid mines can also be used effectively for inland waterways.

Submarine-laid mines, like aircraft-laid mines, are specially configured so they may be launched underwater from torpedo tubes. This is not a primary method of delivery due to the limited space aboard a submarine; however, submarine mines can be delivered at great distances and under utmost secrecy. This method of delivery has a tremendous tactical advantage in mine warfare operations.

Surface-laid mines may be laid in large numbers and, with modern navigation systems, precise accuracy. However, as the Iraqis recently learned during Desert Shield/Storm, one must have control over the anticipated mined area for surface-laying platforms to be effective as mine-laying vessels become easy prey for hostile forces. The surface-laying of mines is very time-consuming and is primarily only undertaken during good weather conditions. Ships or small vessels can be easily modified in a short period of time to accomplish this method of delivery.

Regardless of the type of mine, there are only two methods of actuation, influence and contact. Contact is the most elementary of the two, requiring actual contact by a target vessel for detonation. Actuation is accomplished by either switch horns or chemical galvanic horns. Inexpensive to produce, the contact mine is still a formidable weapon when employed in large numbers.

The modern influence mine detonates when an electrical signal is received from a detector device. The three types of detector devices are magnetic, acoustic, and pressure. The detector, used in conjunction with the firing device, can be a magnetometer, search coil, hydrophone, or pressure device. When the firing mechanism receives a signal from the detector, the signal is analyzed to determine the validity of the target. After the information is analyzed and determined to be a legitimate target and in the appropriate proximity, the firing device sets off the detonator. The proximity of the target is all that is required to set off the influence mine.

The magnetic firing device, as discussed earlier, employs two types of detectors: the search coil and magnetometer. The search coil senses a change in the earth's magnetic axis as the target moves over the proximity or "danger zone" of the mine. Search coils are ideal detectors for bottom mines, assuming a permanent position on the bottom of the ocean floor. Magnetometers are three-dimensional and are ideally suited for moored mines due to changing positions of the mine

in the unstable ocean environment. When the target vessel approaches the proximity zone, the magnetic detectors send a small electrical impulse to the firing device which actuates the mine.

Acoustic detectors utilize a hydrophone to convert the target vessel's propeller or machinery noises into electrical signals for analysis. Certain frequencies are programmed into the detector to prevent detonation by marine life or mine countermeasure operations utilizing explosions and noisemakers. Once the target vessel is operating in the mine's damage zone, a switch is closed which initiates the firing sequence causing the mine to explode.

Pressure detectors utilize electrohydraulic sensors to sense negative or reduced-pressure readings when a target vessel passes over the mine. Normally, actuated pressure firing mechanisms are used in combinations of either pressure-magnetic or pressure-acoustic. This increases the mine's detection capability and ensures survivability during countermeasure operations. This type of detector is also programmed to sense certain types of negative pressures for a valid ship target. This allows the detector to ignore surface swells and wave action and actuate on the proper target. If the detector's programmed setting senses a moving vessel operating in the target zone with a decrease in pressure, a switch is closed and a sequence is initiated which causes the mine to explode.

NOTES

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2. Wettern, p. 91.

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Chapter III

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